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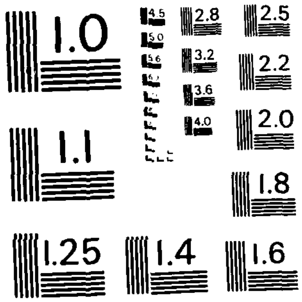

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LOGISTICAL SUPPORTABILITY
OF POWER CONDITIONERS

Prepared by

Mobility Research and Development Command

SCIENCE APPLICATIONS, INC.

FINAL TECHNICAL REPORT

LOGISTICAL SUPPORTABILITY OF POWER CONDITIONERS

Prepared by

Mobility Research and Development Command
Fort Belvoir, VA 22060

By

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Programmed increases of power dependent systems, and advanced concepts for their broad-based employment indicate a vital need to resolve the Army's quantity/quality electrical power problems. In the event of a tactical emergency, sustained reliance on military generators may introduce serious logistical challenges. Replacement of power sources when losses occur may be difficult. Technical support to accomplish paralleling of alternate sources may be in short supply. Demands for precise power to operate critical items may necessitate establishing priorities for

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for electrical usage. Transfer from commercial to military power may cause system failures, especially to high-tech computer based items.

To increase operational flexibility and reduce wear and tear on military generators, the Army should be capable of utilizing any commercial source. However, they must be able to shift to military power sources with minimum interruption.

Power conditioners are the key to resolving the quantity/quality dilemma. They provide a means to operate all military systems from any world-wide power source regardless of voltage, frequency or precision. They are capable of altering the source characteristics of voltage and frequency to match the input requirements of all military equipment.

The Army's problems can be resolved by a 2-unit family of power conditioner modules, 1.5 and 5KW rated. Capable of accepting inputs from 100-480 VAC/50-400 cycles, and 28-400 VDC, they can provide output voltages and frequencies compatible with all equipment and systems in the Army inventory. Battery, fuel-cell photovoltaic or thermoelectric backup should be included to provide UPS capability. Employing advanced solid state technology and modular design, multiples of the 1.5 and 5KW units can be combined to meet conditioned power needs from 1.5 to 60KW.

The ability to provide large quantities of general purpose power and electric quantities of quality of "clean" power reduces the need from precise generators, increases flexibility in power source selection and utility, alleviates combat service support demands, and provides a programmable basis for meeting current and projected Army requirements for electrical power.

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EXECUTIVE SUMMARY

1. This study provides a basis for the design, development, integration and utilization of power conditioners for U.S. military forces.

2. To insure adequate coverage of the subject, provide a broad-based understanding of the problems involved, and determine the best approach for resolving power conditioning issues, three major tasks were undertaken:

   a. Analysis of military electrical power distribution system needs and deficiencies.

   b. Assessment of logistical problems associated with the provision and distribution of electrical power.

   c. Identification of power conditioner characteristics which would resolve logistical problems and improve power distribution capabilities.

3. The primary electrical system findings are:

   a. The Army's need for electrical power could increase dramatically over the next several decades. To implement the air-land battle concept, methods must be devised to insure sustained availability of that power well forward of normal logistical complexes.

   b. The electrical power requirement is basically twofold: large quantities of utility or general purpose power to operate items such as lighting, motors, compressors and other general purpose equipment; and smaller quantities of precise or "clean" power to support higher technology systems.

   c. The Army's fundamental problem is not one of insuring adequate quantities of general purpose electricity. Rather, it is the need to provide "clean" or conditioned power to modern electronic systems and instruments with their inherent sensitivity to surges, spikes, and voltage/frequency drops.

   d. The quantity/quality dilemma cannot be resolved at the generator. Quality failures, even with precise generators, occur when both high and low technology equipment are required to operate on a common distribution grid. Transients associated with low-tech or general purpose

equipment invariably have an adverse effect on high-tech systems.

e. The Army also faces a high-tech distribution dichotomy. Most new systems require 400 cycle power. This is the least efficient frequency for transmitting electrical power over extended distances. Yet new concepts may dictate the need for considerable dispersion of these systems. Without power conditioners, the Army has two options: assign additional (and usually precise) generators at each site; or employ large capacity generators (usually in "overkill" sizes) to cope with line drop problems when supporting multiple sites.

f. Introduction of the power conditioners recommended in this study will eliminate many of the current distribution problems. Units will be able to use any power source at hand. Those critical systems requiring uninterrupted service (UPS) will have multiple on-line, back-up options available. Dedicated generators will be the exception rather than the norm. The need to parallel generators will be eliminated. Quality or "clean" power demands can be addressed more effectively and economically. And low frequencies can be used to more efficiently distribute power to dispersed sites.

4. The primary logistical findings are:

a. Growth of the Army's needs for power to support electrical-dependent systems may follow the same pattern as past needs for fuel to support ground and air mobility vehicles. In those instances, as technological advances were introduced (high compression engines, turbines, etc.) demands -- both in terms of quantity and quality -- increased rapidly. Compounding the problem was a need to distribute the fuel to sites far removed from storage facilities.

b. A similar pattern is developing with electricity. Overall requirements for power have increased many-fold since WWII. Of late, with the technological explosion, the demands for "clean" or conditioned power are rising as well. Furthermore, just as with the ground and air mobility concepts, electronic concepts are extending the power distribution challenge to sites far removed from normal logistical complexes.

c. The quantity problem can be resolved if the Army is able to operate from worldwide power sources -- commercial, organic, allied or captured. The quality problem is not so simple, since demands of both general purpose and precise types of equipment must be met. To complicate the task, oftentimes these two diverse user items are required to operate on the

same distribution system. At other times, units will employ both utility and precise generators to meet their needs, thus complicating the repair and replacement tasks.

d. While the basic need for power conditioners is obvious, it is doubtful that merely providing an input and output capability alone is sufficient to justify a program of any real magnitude. To insure success, the conditioner must be able to address many of the logistical support problems plaguing the Army today. More importantly, it must resolve these technical issues without introducing technical needs of its own. On a competitive basis, the Army's supply of trainable technicians is limited. Trends in high priority tactical and strategic systems are toward greater rather than lesser complexity. The growing inventory of technical line items is placing ever increasing demands on an already overburdened combat service support system.

e. To resolve these issues, an encompassing design approach is proposed. To exploit source availability, multiple input/output capabilities are provided. To reduce technical support, the designs include self-diagnostics, basic go-no-go readout, programmability to eliminate paralleling, and simplified plug-in replacement in the event of failure. To ease the line item load, a minimum of modular units are rcommended which, by using the building block approach, are deemed capable of meeting Army PC requirements up to 60 KW. To ease the replacement problem, the study recommends that smaller units and built-up assemblies of larger units be considered throwaways in critical combat situations. To insure continuity and responsiveness, adequate spares should be included in unit TO&E's.

f. To resolve subsequent requirements on a timely basis, it is advocated that all future systems be introduced into the Army inventory with appropriate PC's as standard components.

5. The primary power conditioner findings are:

a. Power conditioning should be tailored to meet the "clean" power input requirements of user equipment, not the output capacity of power sources (generators).

b. Two basic modules, 1.5 and 5 KW are required. Input capabilities should include 100-480 volts AC with frequencies from 50 to 400 cycles. DC inputs should be from a nominal 28 volts at lower level inputs, and 100 to 400 volts at higher levels. Programmable outputs should be compatible with the needs of all equipment and systems in the Army inventory.

c. Design criteria are: minimum family (2) with maximum utility (from 1.5 to 60+ KW); sizing of built-up PC's based on user needs for clean power (preponderence between 1.5 and 15 KW); reliability to minimize support requirements (state of the art components with self diagnostics, etc.); weight to meet stringent manportability demands (target .025 lbs. per watt); UPS and multi-sorce capable (battery, fuel cell, photovoltaic, thermoelectric); multi-functional (on-site programmable voltage/frequency input/output, self-diagnostic, self- and system performance monitoring); selective throwaway and simple repair/replacement (go-no-go readouts, all-up spares and subassemblies).

d. Ability to operate from multi-sources provides planners and commanders with means to include high-tech equipment and systems in initial phases of combat operations. In addition, it provides the capability to operate with allied forces, and meet demands for worldwide commitment during periods of national or international disaster.

e. Depending on how modules are utilized in meeting user "clean" power requirements, there could be a need for up to 186,000 of the 1.5 KW power conditioners, and up to 169,000 of the 5 KW units.

6. Conclusions:

a. Programmed increases of power dependent systems, and advanced concepts for their broad-based employment indicate a vital need to resolve the Army's quantity/quality electrical power problems.

b. In the event of a tactical emergency, sustained reliance on military generators may introduce serious logistical challenges. Replacement of power sources when losses occur may be difficult. Technical support to accomplish paralleling of alternate sources may be in short supply. Demands for precise power to operate critical items may necessitate establishing priorities for electrical usage. Transfer from commercial to military power may cause system failures, especially to high-tech computer based items.

c. To increase operational flexibility and reduce wear and tear on military generators, the Army should be capable of utilizing any commercial source. However, they must be able to shift to military power sources with minimum interruption.

d. Power conditioners are the key to resolving the quantity/quality dilemma. They provide a means to operate

all military systems from any worldwide power source regardless of voltage, frequency or precision. They are capable of altering the source characteristics of voltage and frequency to match the input requirements of all military equipment.

e. The Army's problems can be resolved by a 2-unit family of power conditioner modules, 1.5 and 5 KW rated. Capable of accepting inputs from 100-480 VAC/50-400 cycles, and 28-400 VDC, they can provide output voltages and frequencies compatible with all equipment and systems in the Army inventory. Battery, fuel cell, photovoltaic or thermoelectric backup should be included to provide UPS capability. Employing advanced solid state technology and modular design, multiples of the 1.5 and 5 KW units can be combined to meet conditioned power needs from 1.5 to 60 KW.

f. The ability to provide large quantities of general purpose power and selective quantities of quality or "clean" power reduces the need for precise generators, increases flexibility in power source selection and utility, alleviates combat service support demands, and provides a programmable basis for meeting current and projected Army requirements for electrical power.

FOREWORD

This study provides a broad-based logistical assessment of military electrical power requirements, together with an analysis of the role of power conditioners in meeting those requirements.

Tactical studies often address singular needs and produce singular solutions. Being "results" oriented, they leave the chore of resolving support issues to others -- invariably, the logistician. Logistical studies, on the other hand, must address a myriad of problems encompassing a multiplicity of support functions. These include supply, maintenance, distribution, recovery, repair, storage, retrieval, inventory and quality control, to name a few. Therefore, for a logistical assessment to be meaningful, solutions must address as many of these functional considerations as possible.

The dynamic growth of power-dependent tactical equipment and systems represents a serious challenge to the logistical system. Of particular significance is the fact that this growth is not limited to quantities of electrical power alone, but includes a need for better quality, or conditioned power, to support higher technology systems entering the inventory. Quantity demands can be met by increasing the number of sources, i.e. generators. Selective quality can be provided by allocating precise generators to support the high technology systems on a dedicated basis. But such a solution, while resolving a portion of the quality problem, would add considerably to the logistical support burden.

For the Army to exploit the dynamic growth in user systems, it requires a dynamic logistical solution capable of similar growth. This study endeavors to provide that solution.

I. INTRODUCTION

A. SUBJECT.

1. This study provides a basis for the design, development, integration and utilization of power conditioners for U.S. military forces.

2. To determine the best approach for resolving the power conditioning issue, three major tasks were undertaken:

   a. Analysis of military electrical power distribution system need and deficiencies.

   b. Assessment of logistical problems associated with the provision and distribution of electrical power.

   c. Identification of power conditioner characteristics which would resolve logistical problems and improve power distribution capabilities.

B. SCOPE.

1. The original purpose of this study was to conduct an assessment of the logistical supportability of power conditioners. While acquiring information upon which to make such assessment, certain shortcomings were identified:

   a. Except for a small number of specialized conditioners integral to high priority systems, and a single on-going test program of a prototype unit, there are no other power conditioners in the current Army inventory.

   b. The power conditioner is but one component of the total power distribution system. To study its function in isolation would narrow the analytical scope and limit the findings to its specific role.

   c. For the findings to be meaningful, other components of the distribution system must be considered as well. These include power sources, distribution grids, and user equipment.

2. Research revealed that the preponderance of power conditioner studies to date addressed specific needs and applications. Furthermore, in most cases the conditioning function was linked to the standard family of military generators. While such efforts did identify problems, they contained few solutions. Therefore, it was decided that:

a. To understand needs, the entire electrical system must be considered, including all output sources, distribution challenges, and user demands.

b. To assess the deficiencies and problems of providing electrical power, quality and quantity degradations of the current system must be identified.

c. To determine functional capabilities required to solve the problems, the full spectrum of source output characteristics versus user input needs must be addressed.

3. Based on these considerations, the original scope was expanded to include the three major tasks listed in paragraph A2 above.

C. APPROACH.

1. The study was accomplished in three phases. Initial effort involved an analysis of the USATRADOC Letter of Agreement (LOA) for a Family of Military Power Conditioners (PC), dated 18 June 1980. This document provided information regarding the need, operational concept, system characteristics and program development. In establishing a mission profile, the LOA stated:

> THE FUNCTION OF ELECTRICAL POWER CONDITIONERS IS TO CONVERT POWER FOR ANY PERIOD RANGING FROM SHORT INTERMITTENT PERIODS TO PERIODS UP TO 24 HOURS PER DAY FOR EXTENDED PERIODS. BECAUSE SOLID STATE TECHNOLOGY WILL BE USED IN THE POWER CONDITIONERS, AND THEY WILL BE ELECTRICALLY CONNECTED TO A POWER SOURCE, TASKING ELEMENTS ARE EXPECTED TO BE BASED ON THAT REQUIRED FOR THE POWER SOURCE. IN THIS EXAMPLE, TASKING IS THAT REQUIRED FOR TACTICAL GENERATORS.

2. A number of questions arose as a result of this analysis: Is there a need for conditioned power when operating from sources other than military generators? If so, is it more efficient and cost effective to design PCs capable of accepting any power source? Are consumer needs for conditioned power common to the generator output and distribution grid, or peculiar to the user equipment terminals? Should power conditioners be connected to the power source or the user equipment?

3. The second phase concerned the overall electrical power distribution system, focussing on its needs and deficiencies. Of particular concern was whether deficiencies resulted from source failures, support inadequacies, or the adverse interaction of diverse consumer loads on a common distribution grid. A major contribution to this analysis was provided by the USATRADOC <u>US Army Power Sources Study</u> (ACN 70608, undated draft). This comprehensive 4-volume study identified numerous system failures, provided examples of practices and quick-fixes employed by the users to cope with problems and maintain readiness, and, more importantly, reflected the futility of attempting to resolve conditioned or "clean" power problems at the source output.

4. The third phase, based on operational and logistical findings, involved a determination of desired PC characteristics and capabilities. This phase required an understanding of current technology. Fortunately, a technical study of power conditioning had been commissioned by MERADCOM concurrently with this logistical effort. The technical author had completed a preliminary assessment and was seeking a definitive basis for determining design criteria and functional capabilities to meet military needs.

5. It was decided that the two study authors would combine their efforts and attempt a common solution. A 3-step approach was used. First, the various problems and deficiencies identified in this study were presented. Next, in concert, the two authors analyzed each item and determined the best solution. Finally, on a state-of-the-art basis, design criteria and functional schematics were developed which best dealt with individual

segments as well as the totality of military electrical power distribution systems. The family of modular power conditioners recommended herein is the result of that combined effort.

6. Technical highlights are included in this study only to the extent that they may provide the reader with an understanding of the recommended solution. An in-depth description and schematic of the power conditioners is contained in the study: Technical Assessment of Power Conditioning (PC) Equipment, A.D. Little, undated (#DAAK-70-83-C0020, task order 0001).

II. DISCUSSION

A. GENERAL.

1. For the third time in less than half a century, the U.S. Army is experiencing a revolutionary change in warfare. The first two -- land mobility in World War II, and air mobility in Vietnam -- presented logistical problems which often impacted adversely on tactical operations. Many of these problems stemmed from a failure to anticipate difficulties encountered when combat action shifted from relatively low to high intensity. Fortunately, the evolutionary pace at which major forces were commited in both conflicts allowed adequate time to organize, equip and train a significant combat service support system.

2. The new revolution -- electronic mobility -- will introduce problems of a nature never before faced by a military force. Quantities of sophisticated equipment will be deployed in areas of high "combat contamination" where logistical impetus will be difficult to attain, and still more difficult to maintain. The demanding readiness posture which the Army is required to assume necessitates that a logistic capability to support the increases be both adequate and responsive. The readiness threat dictates that such capability be available at the earliest date, since commitment could be immediate, inclusive and decisive.

3. In the first two revolutions, POL constituted one of the most severe challenges. Initially, the Army was able to support all fuel users with a common utility grade -- MOGAS. The major task was one of insuring that adequate quantities were available. But as more sophisticated engines were introduced, the problems became both qualitative and quantitative in nature. Methods had to be devised to provide large quantities of quality fuel over greater distances and well forward of normal storage and supply complexes. Similarly, in the electronic revolution, it can be anticipated that the logistical system will be required to provide ever increasing quantities of quality electrical power to user equipments deployed will forward as well as in depth.

B. REQUIREMENT.

1. To accomplish its worldwide strategic and tactical missions, the Army must be able to utilize any available electrical power source -- commercial, allied, captured -- in areas of possible commitment. Furthermore, it must be capable of shifting from commercial to military power with minimum interruption. For those critical systems which must remain operational at all times, a means must be provided to permit uninterrupted transitions from one power source to another. The unreliability of many foreign commercial systems, in both frequency and voltage, dictates that additional means be included to insure that, despite fluctuations in power distribution output, power inputs will remain within the tolerence demands of specific equipment.

2. The Army's requirement for electrical power is basically two-fold: large quantities of utility or general purpose power to operate items such as lighting, motors, compressors and other general purpose equipment; and smaller quantities of precise or "clean" power to support the higher technology systems. When a tailored combination of utility and precise generators is used, these diverse needs usually can be met. But the problem becomes considerably more complex when both high and low technology equipments are required to operate on the same distribution system.

3. To meet the various requirements cited, the Army must be able to operate on input voltages from 100 to 480 volts AC. DC inputs range from a nominal 28 volts at lower levels to 100-400 volts at higher levels. Input frequencies cover the spectrum from 50 to 400 cycles.

4. To exploit the worldwide source options, these various voltage/frequency combinations must be converted or inverted to provide the appropriate match of voltage and frequency to operate military equipment. Thus a power conditioning capability is essential. Furthermore, the conditioning link must be able to accept any voltage/frequency input combination and provide necessary output combinations to operate all

electrical systems in the Army inventory. This is critical to assure interoperability with all power generating sources.

C. CONSIDERATIONS.

1. The Army must rely on both commercial and military power sources. The commercial picture is fairly clear, since the characteristics and capabilities of all national systems are known. The military mobile electrical power (MEP) situation is another matter. In fact, the Army's efforts to resolve MEP problems have not been unlike efforts to "paint a moving train". The current inventory of generators includes multiple variations in wattage, frequency and voltage involving both utility and precise category units. They are powered by different engines requiring different fuels. Models in the field are a mixture of old and new technologies. The flexibility to use multiple generators when increased power is required is either non-existent or entails complex technical support to accomplish. Efforts to standardize on utility type sets is offset by user demands for more precise performance, especially in support of the more sophisticated equipment. Only recently has general officer interest been expressed concerning efforts to maximize standardization and minimize proliferation.

2. The current LOA for a family of military electric power conditioners, dated 18 June 1980, lists eight (8) solid state PC units in ratings to match the DOD standard family of mobile electric power sources. Ratings are listed between 1.5 KW and 200 KW. Based on past progress, and the relatively low priority assigned to power conditioners, embarking on development of 8 separate units could prove overly ambitious. A recent analysis indicates that such an approach might also prove unnecessary. In a majority of cases, the need for conditioned power does not follow so precise a breakout as that of the generator family. Only certain equipment or systems on a given distribution grid require "clean" power. Furthermore, mixing low-tech, general purpose type equipment on the same distribution system with high-tech, precise equipment appears to preclude maintaining quality power throughout the grid. Therefore, the concept of

conditioning power at the generator is questionable, since the first transient introduced by the GP item will contaminate the circuit.

3. Despite the present polyglot inventory, all generators have one characteristic in common. They produce electrical power. Because of the differences in voltage, frequency and precision, however, many are incompatible with specific user needs. Even when compatible, the wide variation in the power consumption characteristics of user equipment on a given distribution system may introduce adverse interactions such as surges, spikes, voltage/frequency drops and the like. While these phenomena may affect general purpose equipment to an extent, their impact on modern electronic equipment and instrumentation can be catastrophic. Results could include interruption of control programs, complete or partial loss of data processing memory banks, and erratic instrument performance. Many of these systems perform real-time collection/collation/analysis/dissemination functions in the C^3I areas. Power failure would destroy continuity and deny retrieval. Since the Army is placing increased emphasis on such systems, it can be assumed that this problem will become more critical with time. While surge suppressors may resolve the primary quality dilemma, they would not be capable of addressing all the other aspects, specifically differences in voltage, frequency precision and uninterruption.

4. Army requirements for power conditioning are extremely diverse. Unlike commercial counterparts, who deal with specific input/output options, the Army's spectrum of options is almost unlimited. Compounding the challenge is the need to operate from numerous sources and satisfy a myriad of both high and low technology users, often operating on a common circuit. Only by separating the utility or general purpose requirements from the precise or "clean" requirements can the problem be reduced to manageable proportions.

D. FUNDAMENTAL PROBLEMS.

1. Since World War II, the Army has introduced order-of-magnitude increases in equipment dependent upon electrical power. Long-range studies indicate this trend may accelerate dramatically over the next several decades. (For example, in 1943, an infantry division had 32 generators to meet its power needs. By 1982, this figure had increased to 1275.) Levels of comparative sophistication have likewise expanded dramatically within the division area of combat responsibility. This indicates a need for immediate resolution of the quantity/quality issue regarding electrical power.

2. The tendency to limit studies to quantitative power output requirements of generators, as opposed to qualitative power input requirements of user equipment, precludes uncovering major problems which may be encountered when the Army is commited to extended combat in areas of limited electrical resources. Some of these problems are:

a. The need to support multiple equipment with diverse power input demands.

b. Increasing demand for electrical power and technicians in areas subject to direct enemy action, and the inaccessibility of such areas to immediate resupply or personnel replacement in the event of combat loss.

c. Competing priorities for shipments of supplies and equipment to forward areas, and the difficulty of locating items with specific capabilities (3, 5, 10, 30 KW generators) and characteristics (utility vs. precise).

d. Inability to utilize alternate electrical power sources (commercial, allied, captured, combinations of remaining generators, etc.) when combat loss is sustained.

3. As pointed out, the basic problem is not the condition of power as it leaves the generating source. It is the condition of that power when it enters the user equipment. Improving generator performance or conditioning power at the output stage will not solve the Army's dilemma. Deterioration of quality will occur as the first transient load from general purpose

equipment is introduced. More importantly, when the differences in quantity and quality demands of equipment on a common distribution system are analyzed, those items needing high levels of quality control often consume lesser amounts of electricity. As an example, the AN/TSC telegraph terminal, installed in an S-208 Shelter, requires 10 kilowatts of power. But only 2.7 kilowatts of power are needed to operate the communications and electronic gear on board. The remaining 7.3 kilowatts are used to support the environmental control equipment. Thus, less than 30% of the power being provided must be conditioned or "clean." In such a situation, assigning a 10 KW power conditioner could be considered an "overkill."

4. According to the LOA, the Army has programmed a family of eight power conditioners in sizes from 1.5 to 200 KW. It is questionable, however, whether those larger than 30 KW would be cost effective. Generators in the 1.5 to 5 KW range make up seventy-nine percent of the current inventory. Those in the 10-15 KW categories total another 16 percent. The remaining generators larger than 30 KW are but 5 percent. Furthermore, as has been shown, cumulative conditioning needs on a given distribution system do not necessarily match to the total output of the generator. In fact, if the example cited in paragraph D3 above is representative, the conditioning need may be considerably lower, with a majority of individual system needs falling between 1.5 and 15 KW. This indicates that the Army would be better served with a family of power conditioners able to address intermediate levels of "clean" power up to the 15 kilowatt figure, with modular growth capability above that level as required.

5. The impact of another electronic item on the Army logistical system must also be considered. Each additional line item programmed taxes an already overtaxed inventory. The need to select and deliver eight PCs to support eight generators would be burdensome. Competing technical programs are fast depleting the Army's limited pool of trainable technicians. If for no other reason, the number of PC makes and models should be kept to a minimum, and the design simplified so that sustained support of critical systems can be accomplished without the need for a broad based logistical organization to perform the supply, maintenance and repair functions. The

concept of throwaway, built-up modular component replacement, simplified self-diagnostics and go-no-go readouts would alleviate many of the logistical problems. Assigning power conditioners to units on the basis of their "clean" power needs would resolve the quality issue. Providing additional PC capability when a unit requires conversion of the total distribution system would resolve the quantity problem as well.

6. To provide uninterrupted power to critical systems, a continuous on-line battery backup should be included in the design. To prevent triggering a proliferation of batteries, the backup capability should be limited to those systems or equipment which must remain operational at all times. The battery capacity should be limited to the power/time required to bring organic generators on-line. Under certain operational conditions (e.g., stealth, silence, minimum signature, etc.) additional backup with batteries or other silent sources may be provided.

E. DESIGN APPROACH.

1. To meet the operational and logistical requirments covered herein, a design concept study was accomplished. Trade-offs, using the LOA, served as a means for determining the minimum family required to satisfy the Army's power conditioner needs. Primary focus was on the high density requirements from 1.5 to 30 KW. The results show that two units -- a 1.5 KW and a 5 KW -- were able to cover the spectrum of options. Technical details of the two PC designs are included in a companion study by A.D. Little: Technical Assessment of Power Conditioning. Criteria and approach reflected in this study are validated by the findings contained in the technical report.

2. The following design criteria were established:

a. Minimum family/maximum utility.

b. Sizing based on user needs not generator capabilities.

c. Reliability to minimize support requirements.

d. Weight to meet stringent manportability demands.

e. UPS and multi-source capable.

f. Multi-function with self-diagnostics.

g. Throwaway and simplified repair/replacement.

3. To satisfy established criteria, the following design objectives should be met, when feasible:

a. Family/utility

(1) 2 basic units = 1.5 KW and 5 KW.

(2) Modular building blocks ≈ from 1.5 KW to 30 KW+.

(3) Field programmable and selective.

b. Size

(1) Based on user conditioned power requirements.

(2) Means of separating "clean" from dirty power.

(3) Flexibility to tailor to specific user systems.

c. Reliability

(1) RAM to minimize technician skill levels.

(2) Hardened to permit adverse terrain employment and withstand nuclear effects.

(3) Servicing reduced to simplified 1st echelon.

d. Weight

(1) Both units manportable in modular configuration.

(2) Trade-offs based on criticality of need.

e. UPS/multi-source

(1) Battery backup with charging capability.

(2) Multi-source input (commercial, generators, fuel cells)

(3) Capable of multi-source usage without paralleling.

f. Multi-function/self-diagnostics

(1) Provide quality/quantity by type.

(2) Ability to accept all inputs, provide all outputs.

(3) Above to be accomplished through selective programming.

(4) Self-monitoring, self-diagnostic.

(5) Capable of monitoring and reporting system performance.

(6) Maintenance decisions limited to go-no-go.

g. Throwaway/repairability

(1) 1.5 KW unit considered throwaway.

(2) 5 KW limited repair, throwaway components.

(3) 5 KW subassemblies built-up/modular.

(4) Both units provide go-no-go information.

(5) 1.5 KW all-up spares; 5 KW built-up subassembly spares.

(6) Self-diagnostics to make maintenance and repair decisions.

F. ADVANTAGES.

1. Matching power conditioners to user equipment needs resolves a number of long standing problems. Since the modular concept will permit precise tailoring of wattage, voltage and frequency, the need for dedicated, precise generators for this specific purpose can be eliminated. The past practices of employing multiple generators or oversized generators to insure adequate power can be discontinued as well. The variable input/output capability will allow units to rely more often on commercial power. This will reduce the cost, support needs and wear-and-tear on organic generators. The integral battery backup will permit critical combat systems to utilize commercial power without fear of losing their software banks in the event of power interruption or degradation. The modular and building block concepts will eliminate one of the most cumbersome and demanding support challenges, that of paralleling multiple generators when additional or alternative

power is required. Lastly, the introduction of only two basic power conditioners able to address current and future requirements will permit a rapid, reliable and cost effective solution.

2. From a logistical standpoint, the recommended program will resolve still more problems. Paralleling has been covered. By including a simple self-diagnostic capability within the control portion the need for highly trained maintenance specialists is all but eliminated in the forward areas. Designing the 1.5 KW module as a throwaway equivalent, and considering components of the 5 KW module as throwaway under certain combat conditions (with built-up component replacements standard) would eliminate many critical supply and resupply actions during intense combat situations.

3. Assigning power conditioners as TO&E items based on conditioning needs will simplify the allocation and distribution problem. Providing conversion capability from 50 to 400 cycles will insure more flexibility and efficiency in the distribution of electrical power. By using the 50 or 60 cycle frequency as the carrier, and converting to 400 cycles at the equipment, greater loads from larger and more efficient sources can be transmitted over longer distances.

4. The most significant advantage of power conditioners will accrue in joint, combined and special operations. The ability to operate from Army, Navy or Air Force power sources, as well as any indigenous source, permits planners to include high technology systems in such operations. Because essential power will be available immediately, such equipments can be introduced during the initial phases of execution. This is critical to joint and combined force commanders (particularly the RDF) since they must rely on technology rather than mass to achieve early tactical and strategic advantages.

5. Combined operations involving allied forces and equipment have always suffered from a lack of standardization. This is particularly true of electrical power because military systems normally match the power characteristics of the various national systems. Being able to operate

without regard to national differences will go a long way toward achieving interoperability among allied forces. QSTAG 683 provides a solid basis for refining the final design of the power conditioners.

6. U.S. forces must be prepared for worldwide commitment during periods of national or international disaster. The same immediacy of joint and combined operations applies, since minimum warning is the norm for such events. Over and above military commitment, the highly flexible PCs would have applicability in international programs under the responsibility of other government agencies. It is said that technology is the key to rapid results in third-world development. Exploitation of that technology depends upon availability of quality electrical power.

G. PROGRAM CONSIDERATIONS.

1. In the past, critical shortages of combat service support equipment were overcome by utilizing commercial items to a maximum extent. This practice proved feasible as a stop-gap until production lines meeting military specification were established. In most instances minimum redesign or product modification was required since many of the advances in commercial development stemmed from military R&D programs.

2. The above does not necessarily apply today, especially concerning computer-based and solid state systems. A technological explosion is occurring in the commercial arena with very little military involvement. A recent MERADCOM survey of power conditioners identified some 260 different units on the market. Only 10 percent were in any way compatible with military needs, and they were designed for specific application in all-up systems. The remainder fulfill unique commercial demands. Unlike past mobilization situations, none of the above items could meet military requirements without major modification.

3. For the military program to be competitive, the Army must identify the magnitude of its PC requirement. A program involving relatively small numbers of production units (especially when accompanied by the

typical adminstrative overload common to military programs) may not be viewed by commercial manufacturers as an attractive deal. On the other hand, a large program with recurring production potential and national and international implications would entice many competitors.

4. Based on the DOD Standard Family of Generators, 1981, the PC requirement appears significant. Depending on how they are used, there could be a need for up to 186,000 of the 1.5 KW units and up to 169,000 of the 5 KW units. While these figures are tentative, they do provide an indication of the program potential. Assuming that a state-of-the-art assembly line could approach a dollar-per-watt cost, the final price tag could exceed $1 billion.

H. PROGRAM APPROACH.

1. As a first step, user branches and services shold be surveyed to determine requirements for conditioned or "clean" power to operate TO&E equipment. Included in the survey should be an assessment of total distribution system needs when operating from commercial sources. This would identify the number of 1.5 and 5 KW modules required to support present equipment.

2. Next, a similar survey should be conducted to address equipment and systems in the RCT&E phases, so they may enter the inventory with essential PC units available.

3. Finally, to preclude proliferation of special purpose power conditioners in the interim, procedures should be established to insure that all future systems include necessary PC interfaces as a part of the system integration effort.

4. Early identification of cumulative needs will provide a valid basis for conducting accurate cost estimates, designing the most efficient fabrication approach, and determining facility needs and production rates.

I. OBSTACLES.

1. The military requirement for power conditioners is both larger and more critical than had been assumed. Convincing the Army of this may take considerable effort. Whereas the problems are primarily associated with quality inputs to select equipment, a preponderance of analyses to date have dealt with quantity outputs of sources. This has caused the Army to seek solutions through increases in sizes, types and numbers of power sources, rather than improvements in the differentiation and distribution of the power itself.

2. Each arm and service requiring electrical power appears to be pursuing its own problem solving program. In most cases, proposed solutions are based on the fallacious assumptions that precise generators will provide the equivalent of conditioned power under all conditions, that larger amounts of power will insure greater reliability, and that multiple generators will solve every conceivable problem.

3. Many references can be cited as contributing to the power system dilemma. One stands out above all others. In FM 20-31, it is stated that "generators are a common user end item." From a TO&E standpoint this may be true, but from a functional standpoint is erroneous. Electrical power is the common user end item, and it is the demand for quality of that end item which is causing the Army its problems. Giving each "proponent" the authority to develop its own independent solutions may result in a series of costly but ineffective quick fixes.

4. The modular family recommended herein, with its ability to satisfy a multiplicity of military needs, appears to be the most feasible and least costly way to resolve the problems. Diverting funds and effort to individual solutions can only delay, and possibly deny, the launching of an essential program to correct the current power conditioner deficiencies.

III. CONCLUSIONS

1. Programmed increases of power dependent systems, and advanced concepts for their broad-based employment indicate a vital need to resolve the Army's quantity/quality electrical power problems.

2. In the event of a tactical emergency, sustained reliance on military generators may introduce serious logistical challenges. Replacement of power sources when losses occur may be difficult. Technical support to accomplish paralleling of alternate sources may be in short supply. Demands for precise power to operate critical items may necessitate establishing priorities for electrical usage. Transfer from commercial to military power may cause system failures, especially to high-tech computer based items.

3. To increase operational flexibility and reduce wear and tear on military generators, the Army should be capable of utilizing any commercial source. However, they must be able to shift to military power sources with minimum interruption.

4. Power conditioners are the key to resolving the quantity/quality dilemma. They provide a means to operate all military systems from any worldwide power source regardless of voltage, frequency or precision. They are capable of altering the source characteristics of voltage and frequency to match the input requirements of all military equipment.

5. The Army's problems can be resolved by a 2-unit family of power conditioner modules, 1.5 and 5 KW rated. Capable of accepting inputs from 100-480 VAC/50-400 cycles, and 28-400 VDC, they can provide output voltages and frequencies compatible with all equipment and systems in the Army inventory. Battery, fuel cell, photovoltaic or thermoelectric backup should be included to provide UPS capability. Employing advanced solid state technology and module design, multiples of the 1.5 and 5 KW units can be combined to meet conditioned power needs from 1.5 to 60 KW.

6. The ability to provide large quantities of general purpose power and selective quantities of quality or "clean" power reduces the need for precise generators, increases flexibility in power source selection and utility, alleviates combat service support demands, and provides a programmable basis for meeting current and projected Army requirements for electrical power.

EXPERIENCE HIGHLIGHTS OF

BG Eugene M. Lynch, USA-Retired

1972-74	-	Military Assistant, Tactical Warfare Programs, Defense Research & Engineering, Office Secretary of Defense. Reviewed, analyzed, coordinated and advised on 160 major R&D industry programs, Army-Navy-Air Force; annual value - $2.7 Billion.
1971-72	-	Commanding General, US Army Flight Training Center & Ft. Stewart, Ga. Responsible for advanced helicopter training of over 2,000 US and Allied students; planned and provided logistical support to 20,000 National Guard and Army Reserve forces during summer training; responsible for general management of all activities and services for 28,000 active and retired personnel. Budget of $34 Million.
1970-71	-	Deputy Inspector General of the Army. Supervised major investigations of personnel, administrative, contractual and procurement activities; conducted inspections and analyses of operations, management practices and administrative procedures in major staff headquarters and commands.
1969-70	-	Chief, Aviation Warrant Officer Branch, Dept. of Army. Managed career program for over 12,000 Army Aviation Warrant Officers; coordinated requisitions and assignments; developed curricula for civil and military technical schooling of selected personnel, designed 30-year career program including training, assignments and promotions.
1968-69	-	Deputy Aviation Officer, US Army Vietnam. Coordinated operations, administration, maintenance and logistical support for 75,000 aviation personnel and 4,000 aircraft. Infantry Brigade Commander; commanded up to seven battalions in combat until wounded in action.
1965-68	-	Member of Graduate Faculty, US Army Command and General Staff College. Taught advanced tactical, logistical, administrative and management subjects to annual student body of 1,400 US and Allied Officers. Was Chief of Corps and Army Section, Department of Larger Units, and the Director, Department of Joint, Combined and Special Operations.
1959-62	-	Aviation and transportation R&D specialist in the United Kingdom and NATO Countries for Department of the Army and Defense. Evaluated R&D proposals in aviation and transportation fields; served on two NATO Armaments Committees as US Representative; negotiated research, development and test contracts with foreign civilian and government-owned firms; monitored civil and military programs and coordinated information exchange agreements; served as US project officer on the Hawker Harrier (P.1127) V/STOL strike fighter aircraft.

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